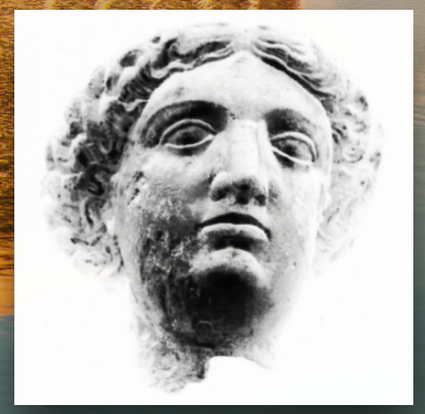
MINERvA in 10 Minutes

New Perspectives 2017

Fermilab

June 5, 2017

Marianette Wospakrik
University of Florida
(Representing the MINERvA collaboration)



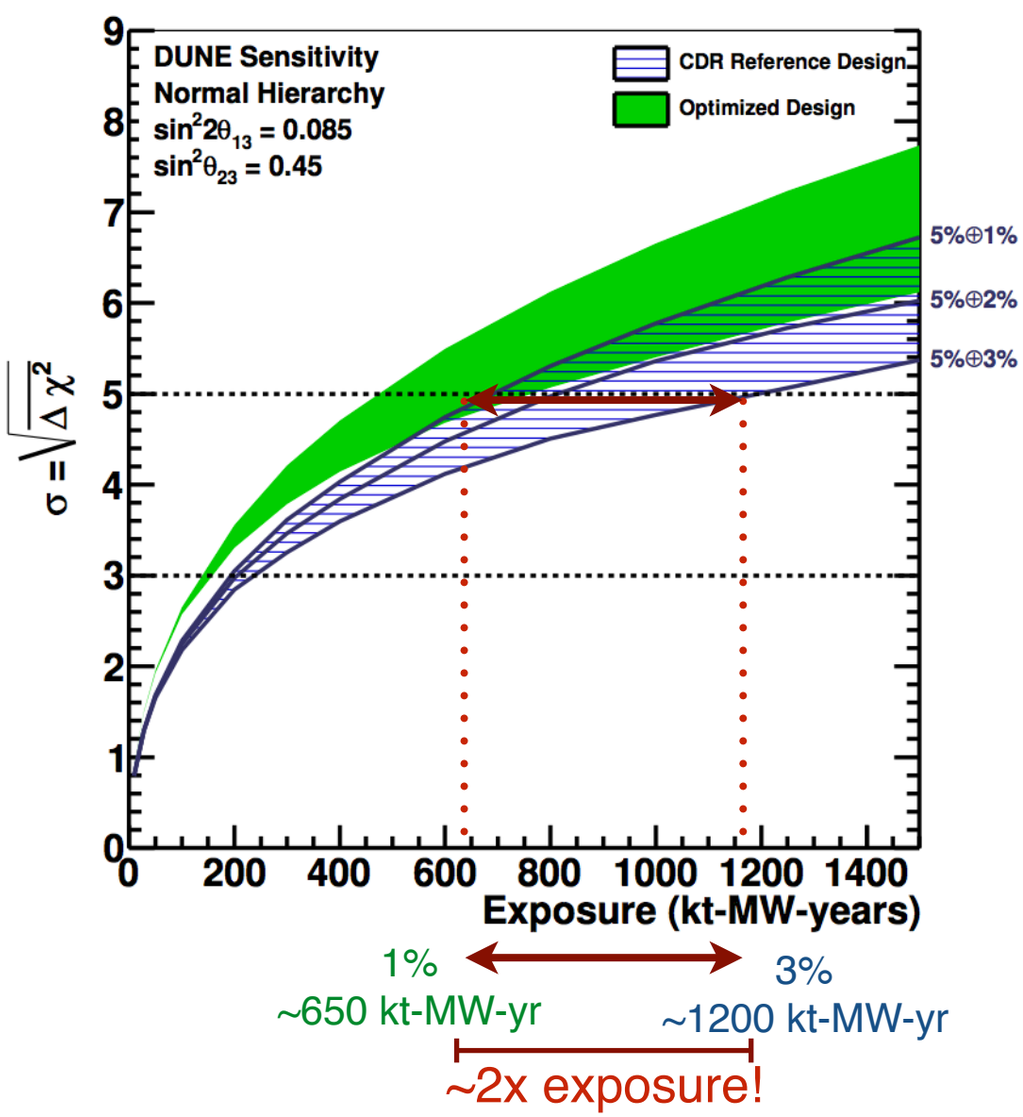
What is MINERvA?

- **MINERvA**: a dedicated on-axis neutrino-nucleus scattering experiment running at Fermilab in the NuMI (Neutrinos at the Main Injector) beamline.
- Our goal:
  - Make **high precision measurement of neutrino interaction cross sections** in the energy region of interests (1-10 GeV).
  - Detailed study of **nuclear effects**

Why care about cross section?

"We know neutrinos oscillate, but do they violate CP?"

DUNE CDR, arXiv:1512.06148

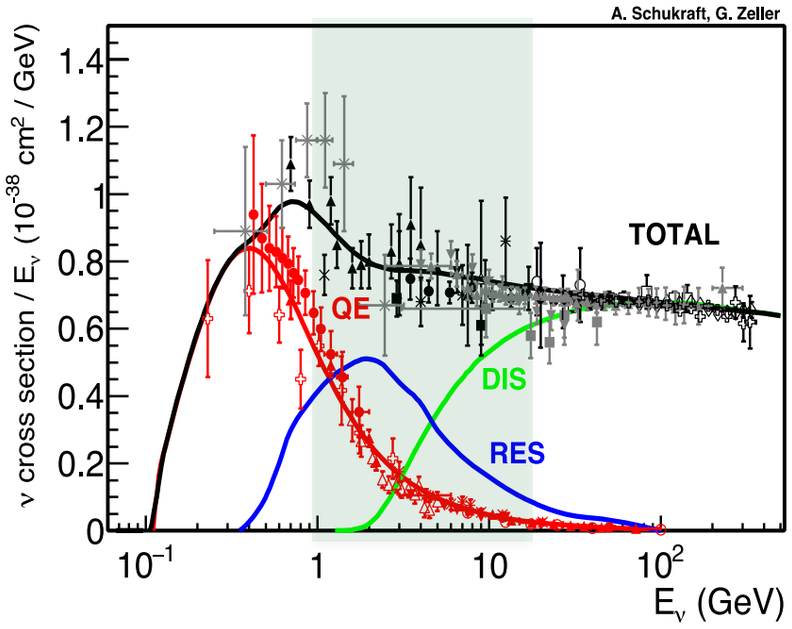


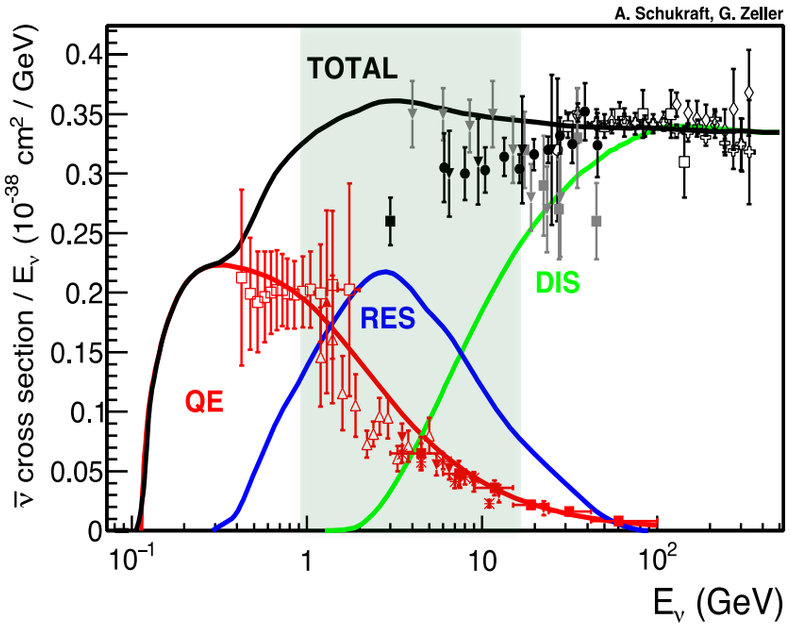
*) **300 kt-MW-years** corresponds to **7 years** data-taking

- In a period of precision neutrino oscillation measurements
  - Reducing systematics uncertainties is critical
- Reaching low systematics goals requires control of all systematics, e.g. neutrino interaction cross sections.
- Accelerator-based oscillation experiments rely on neutrino-nucleus interaction models in neutrino event generators (e.g. GENIE, NuWRO, etc. *insert your favorite neutrino generator here*).
  - Need high precision data to improve model ⟶ goals of MINERvA

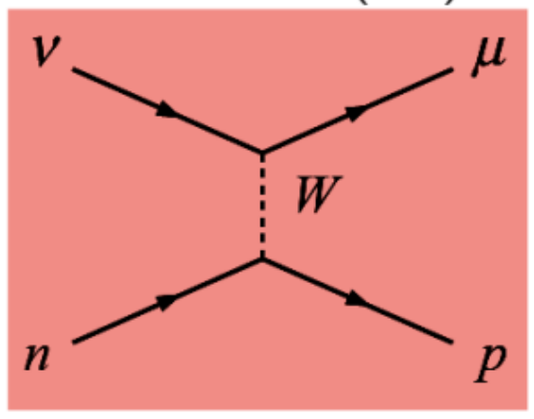
Charged Current Interaction

- Oscillation experiments (DUNE, NOvA, T2K, etc.) measure neutrino energy Ev in the 1-20 GeV region, where many interactions channels are active.
  - These interactions channels are signal and the majority of backgrounds in the oscillation experiment

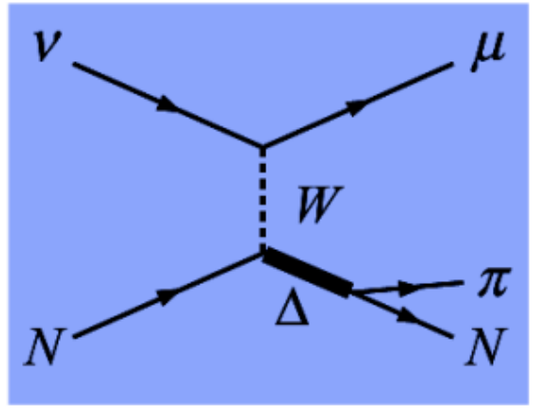




Quasielastic (QE)



Resonance



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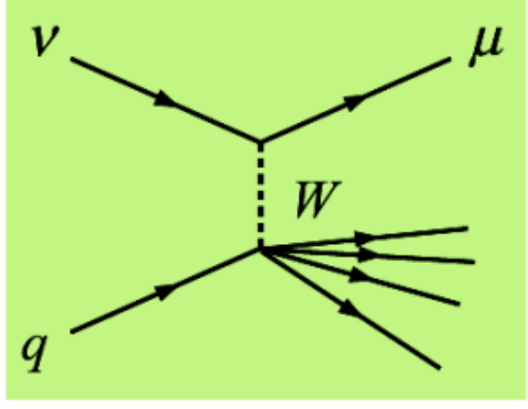

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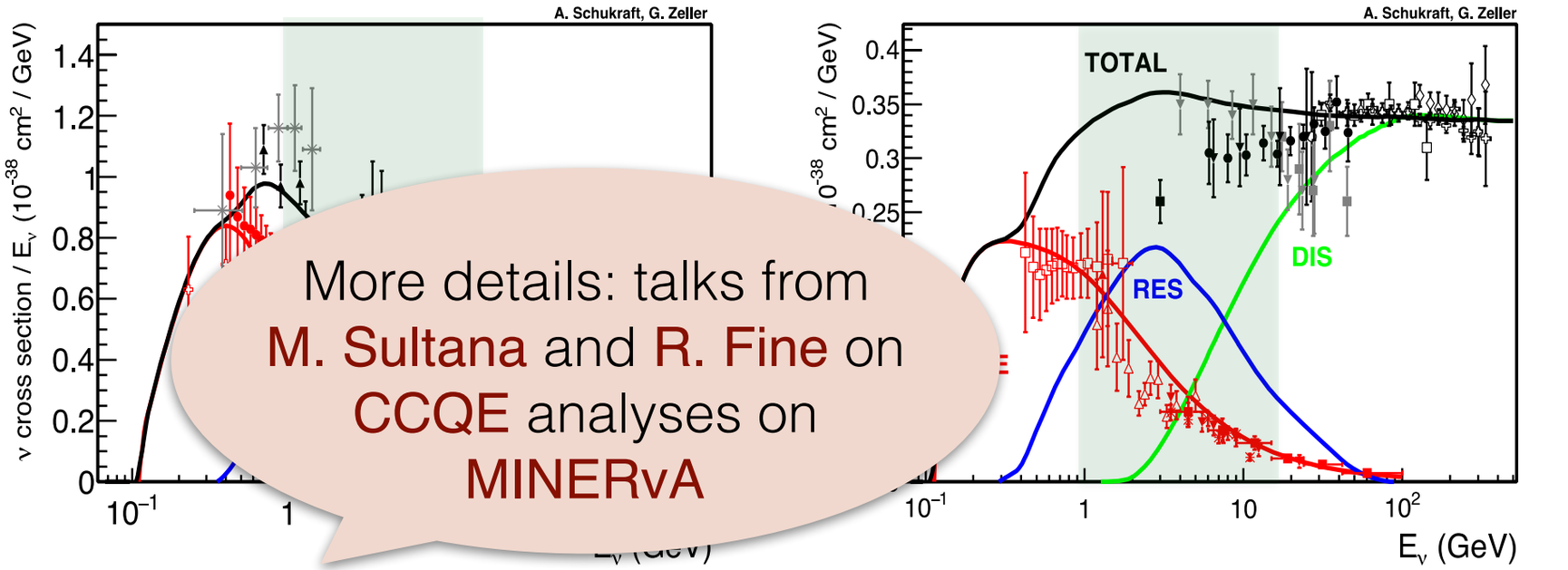

More details: talks from M. Sultana and R. Fine on CCQE analyses on MINERvA

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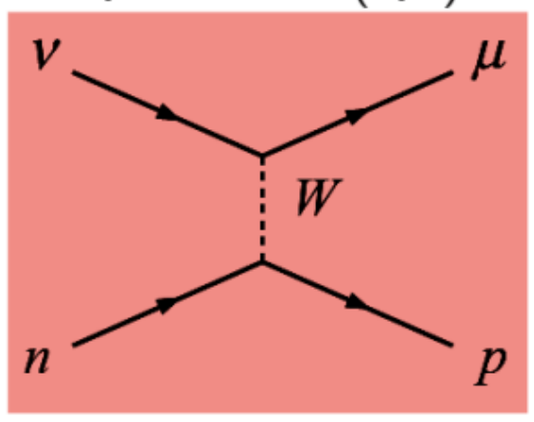

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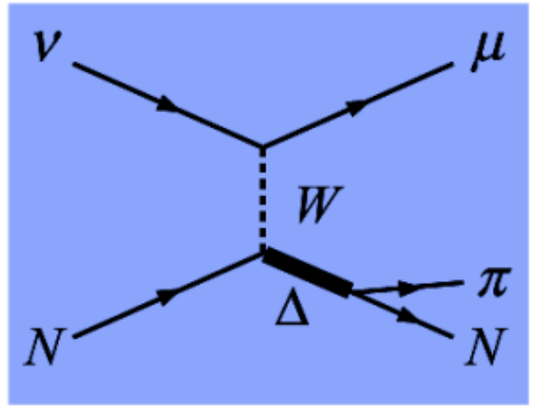

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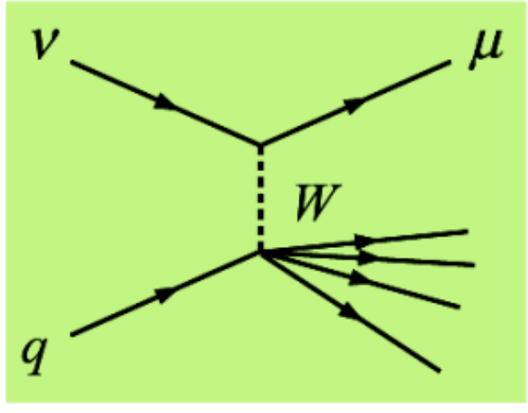

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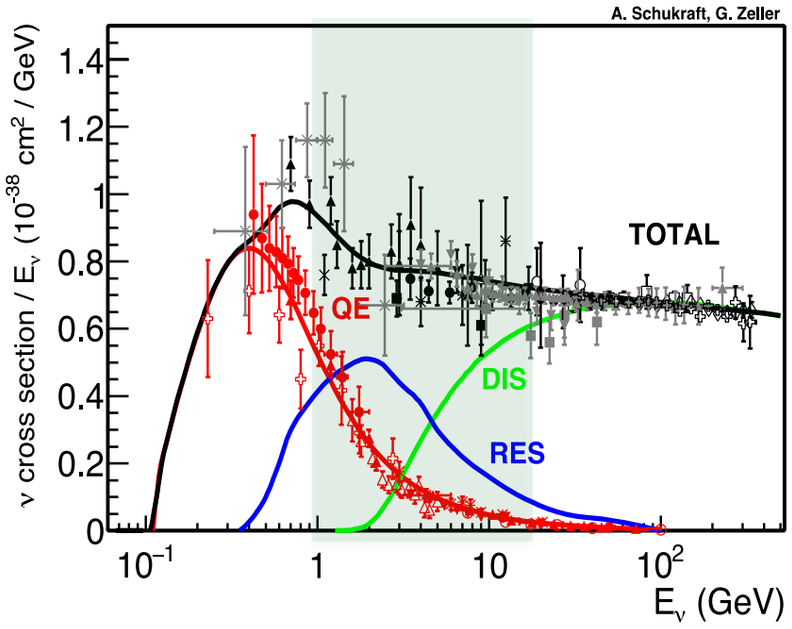

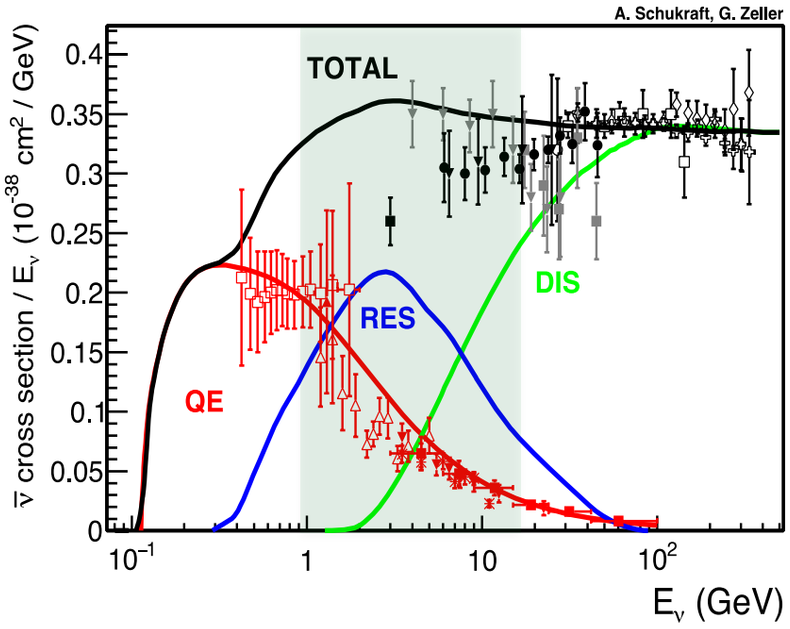

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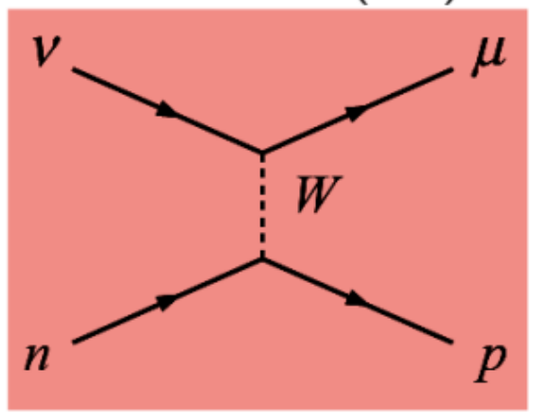

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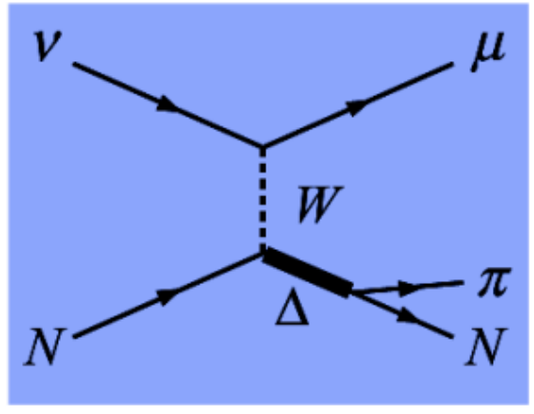

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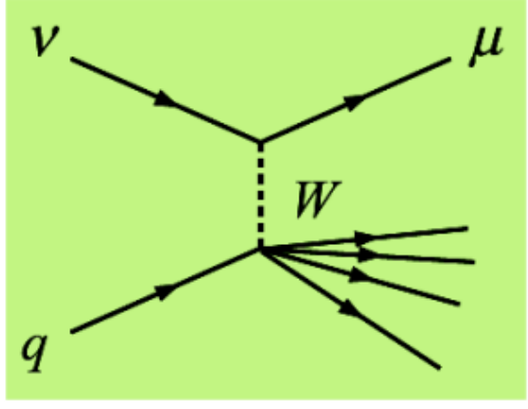

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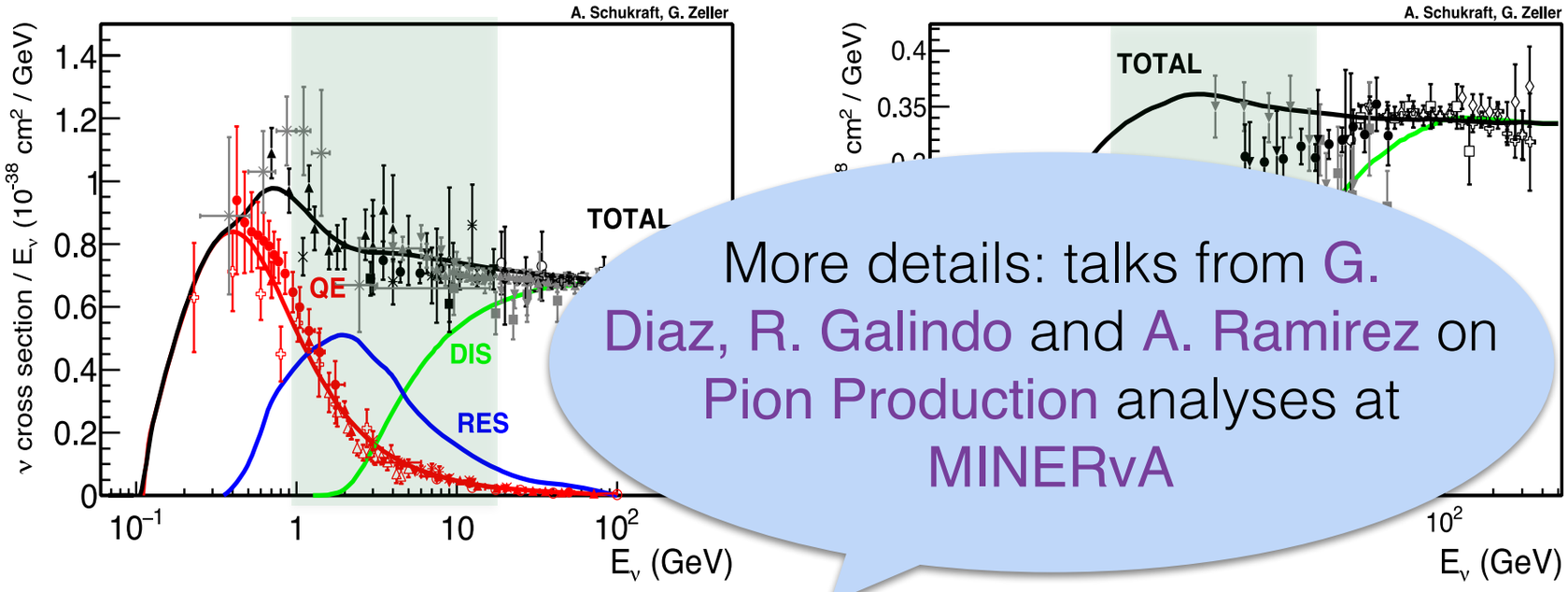

More details: talks from G. Diaz, R. Galindo and A. Ramirez on Pion Production analyses at MINERvA

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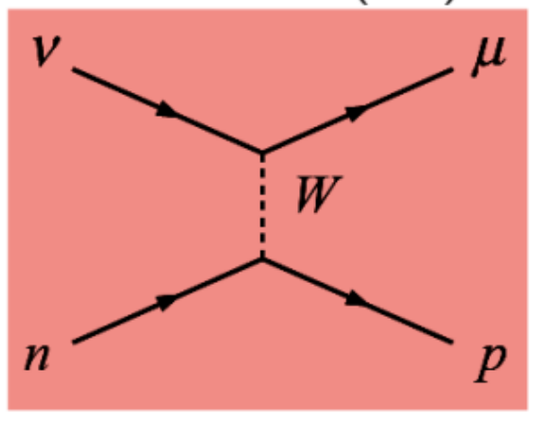

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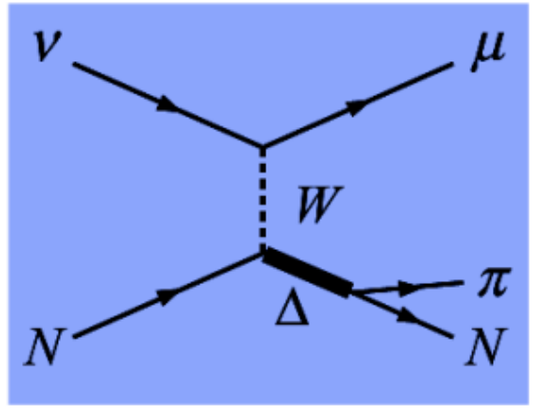

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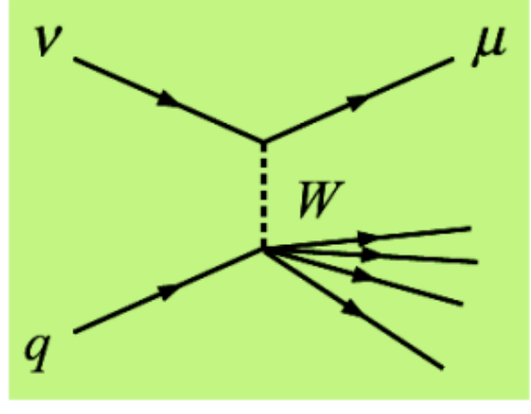

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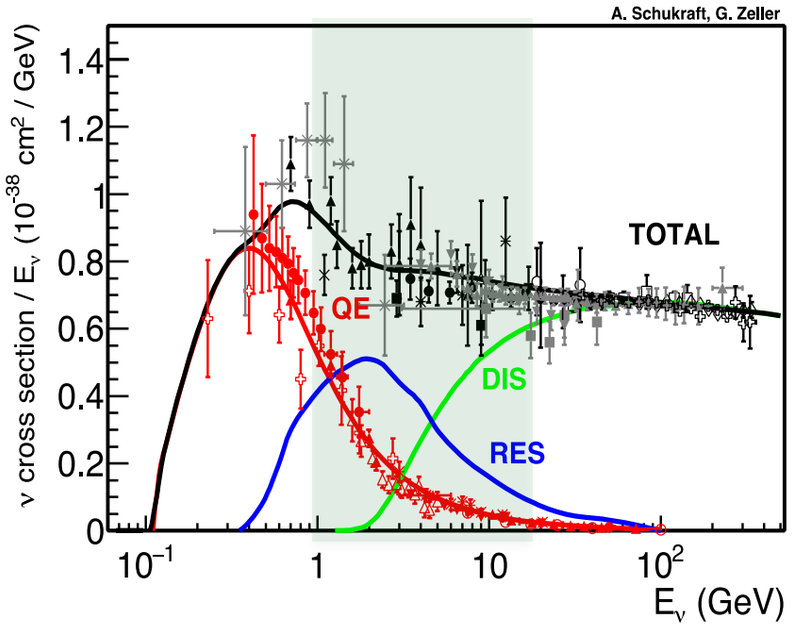

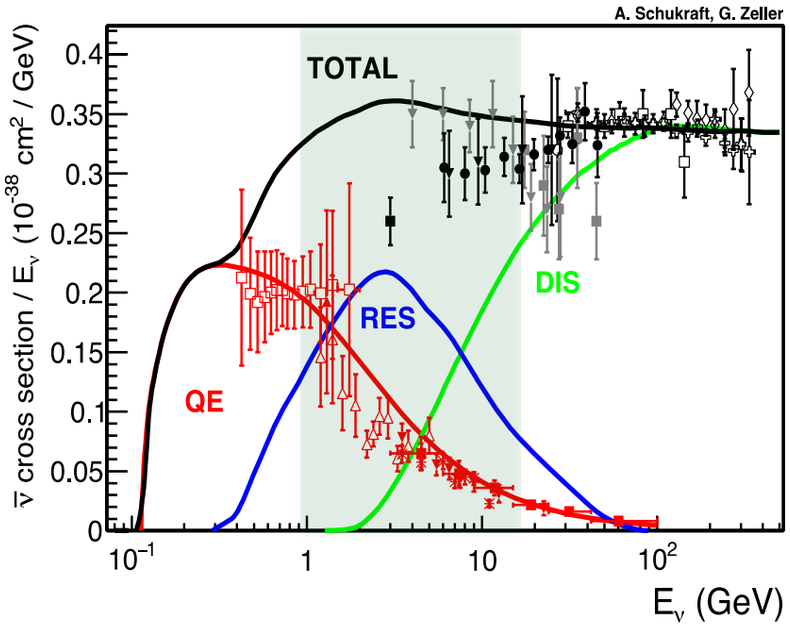

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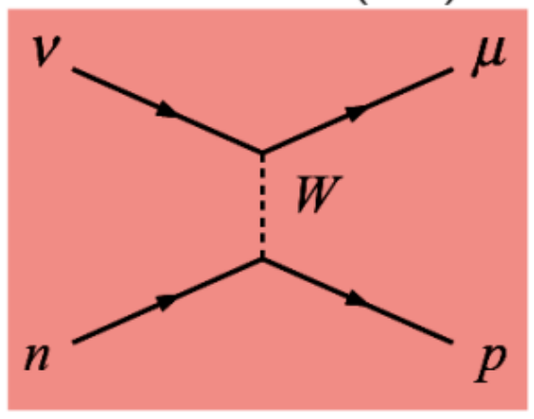

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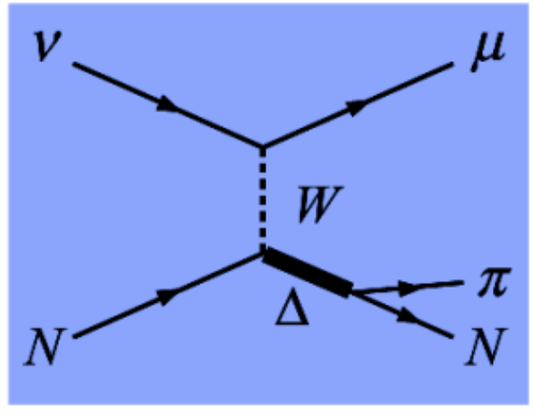

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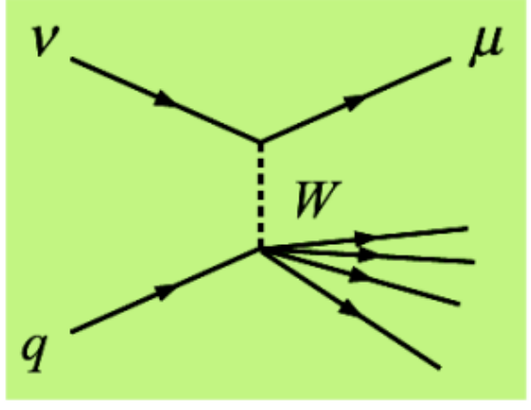
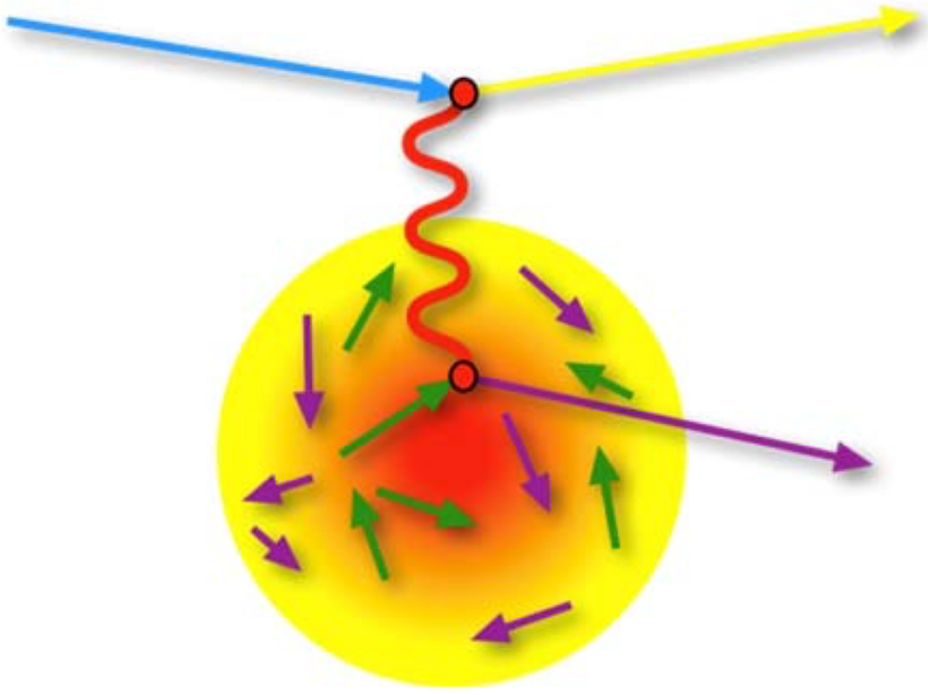


Expectation…….

Don't Forget Nucleus!

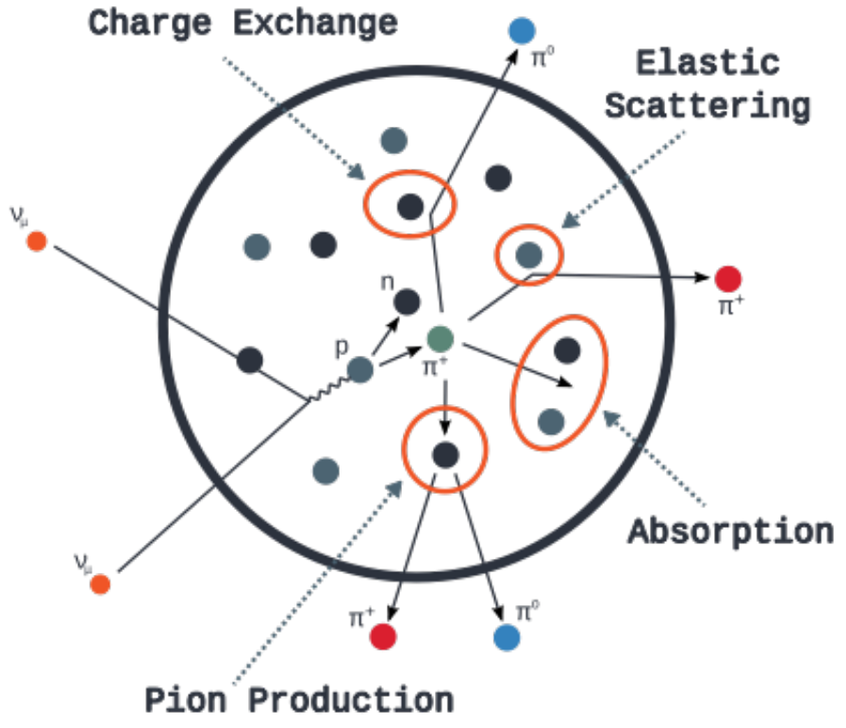
Reality…….

Initial State Nuclear Effect



- Short, medium, and long range nucleon-nucleon correlations on the initial condition, e.g. "2p2h" effect , "RPA" effect

Final State Nuclear Effect



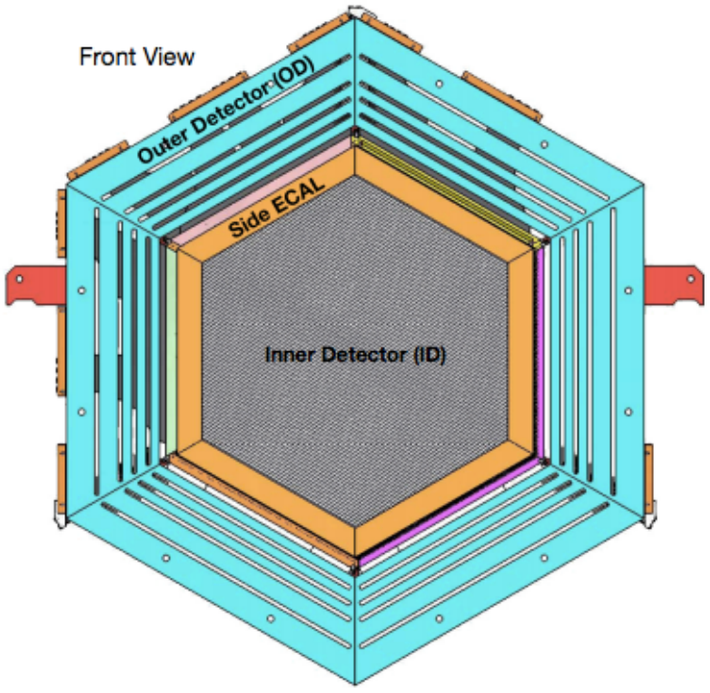
- Particles created have to work their way out of the nucleus, e.g. absorption

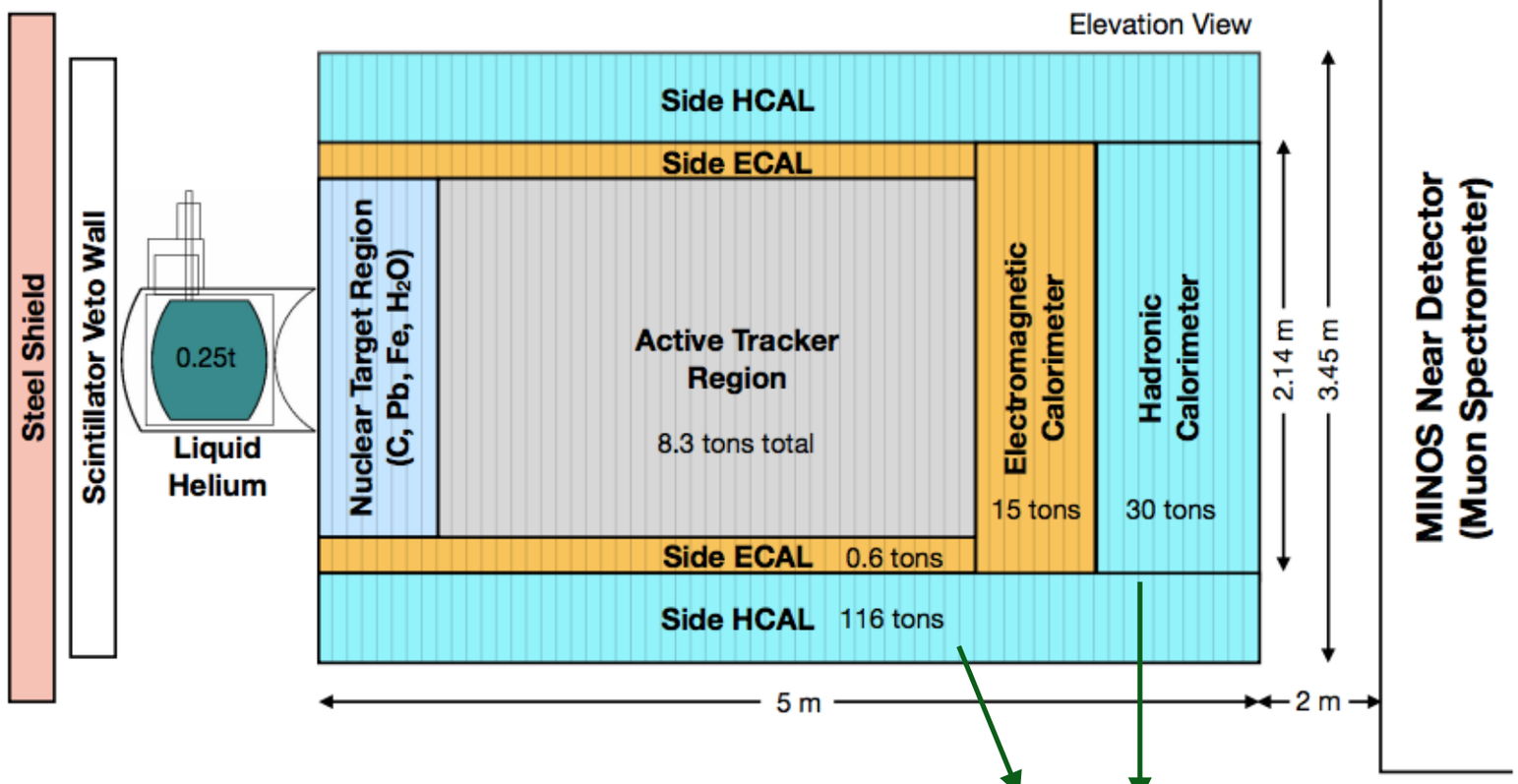
Signal ↔ Background Migration

MINERvA provides detailed description of final state particles and information on big source of uncertainties in the neutrino interaction!

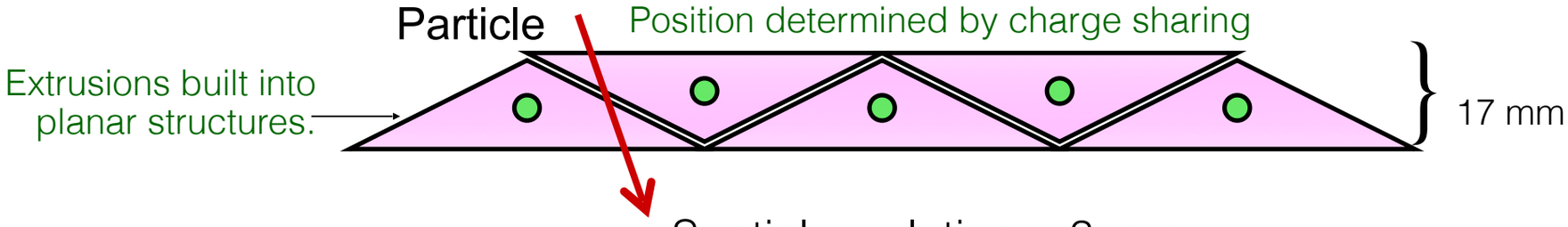
MINERvA Detector

Nucl. Inst. and Meth. A743 (2014) 130



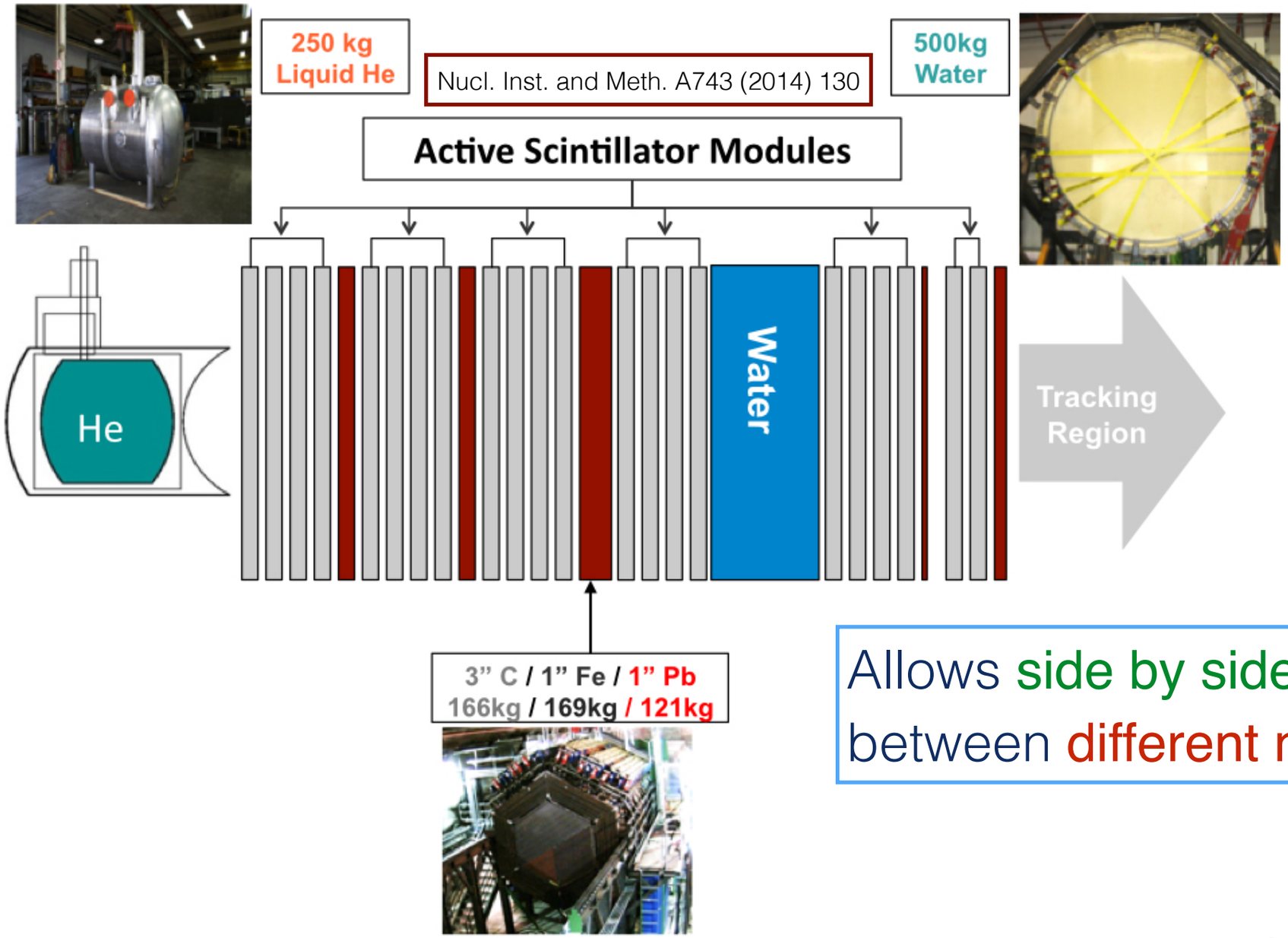


full event containment



Spatial resolution: ~3 mm
Timing resolution: ~3 ns

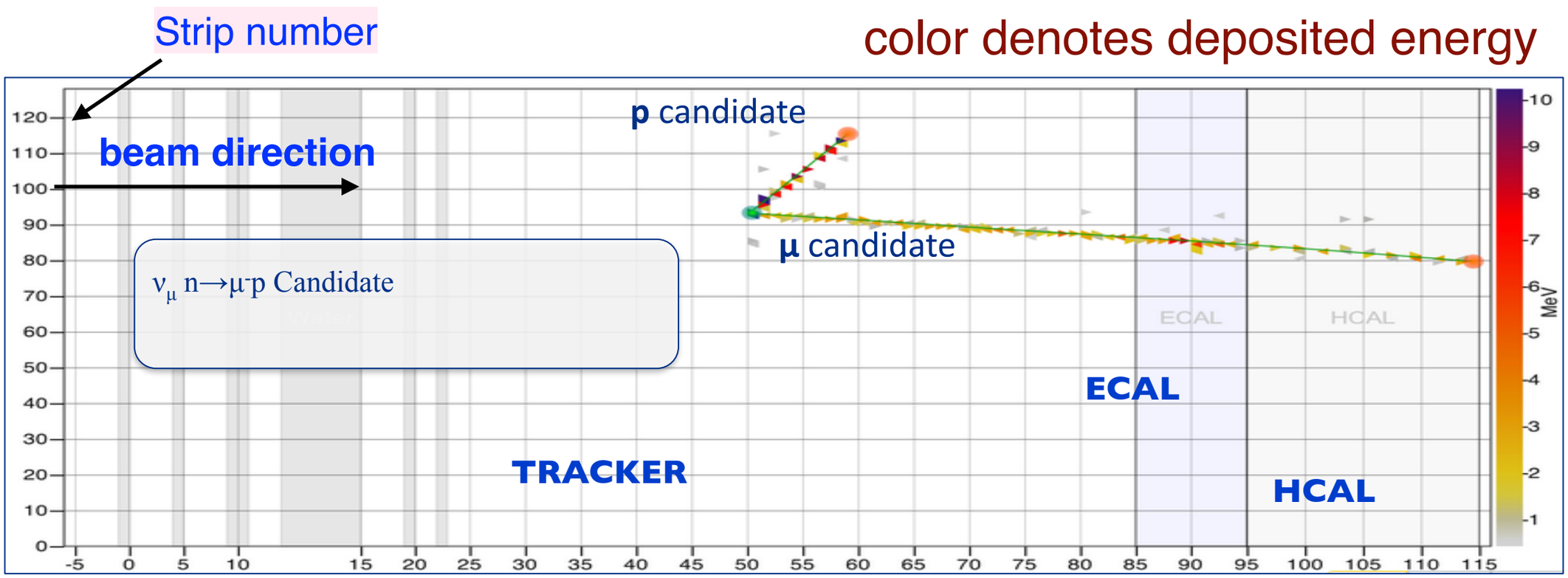
MINERvA Takes Data on Many Different Targets, Simultaneously!



Allows side by side comparisons between different nuclei

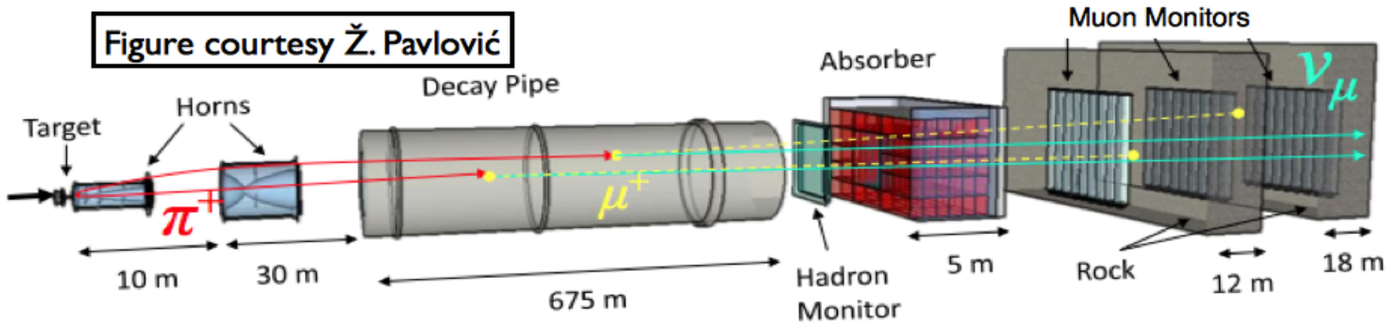
1

MINERvA CCQE Events

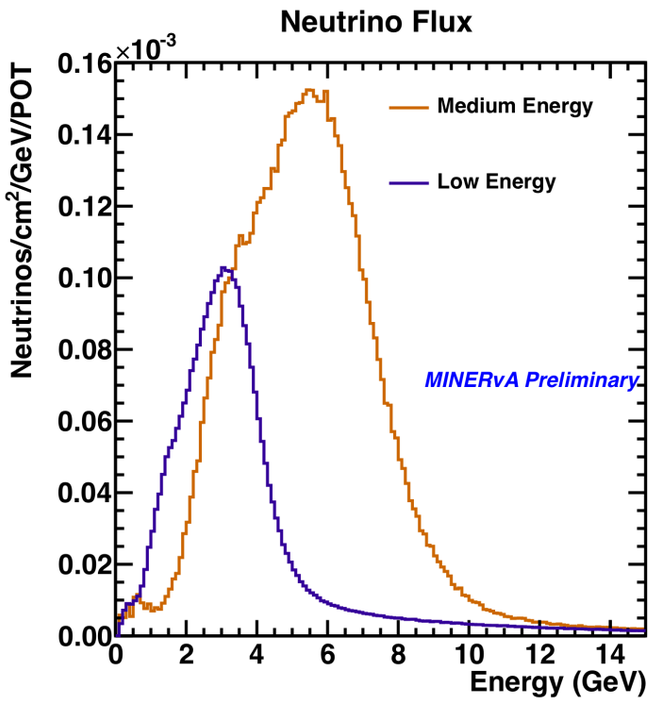


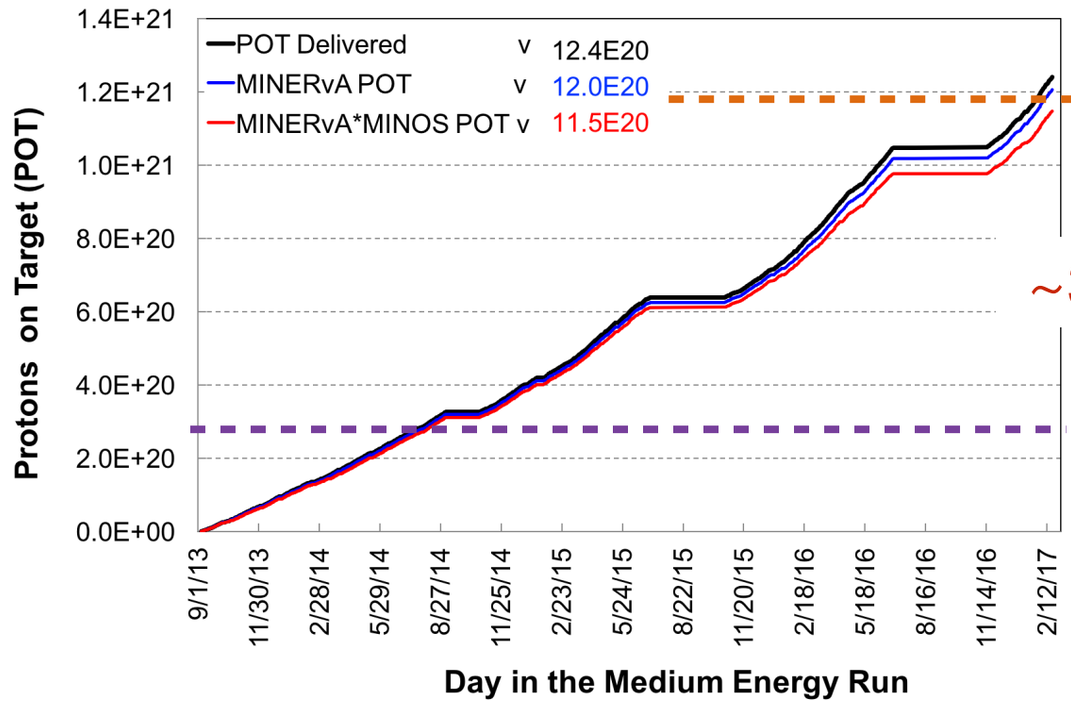
Two planes of scintillator strips makes a *module*

Neutrino Beam and Flux



MINERvA





ME POT

~3x increase

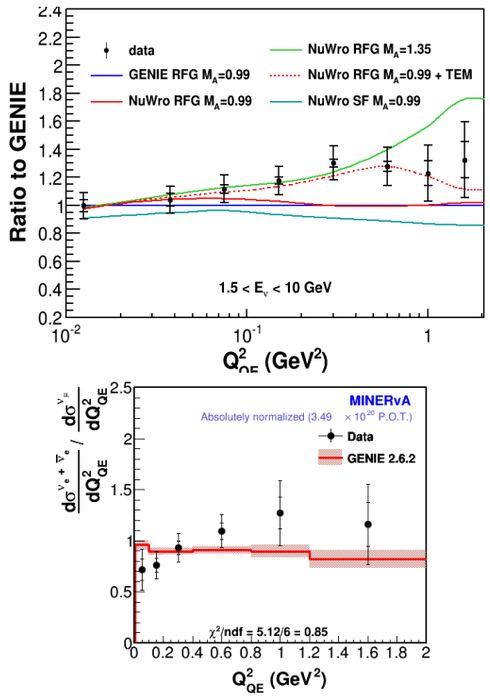
LE POT

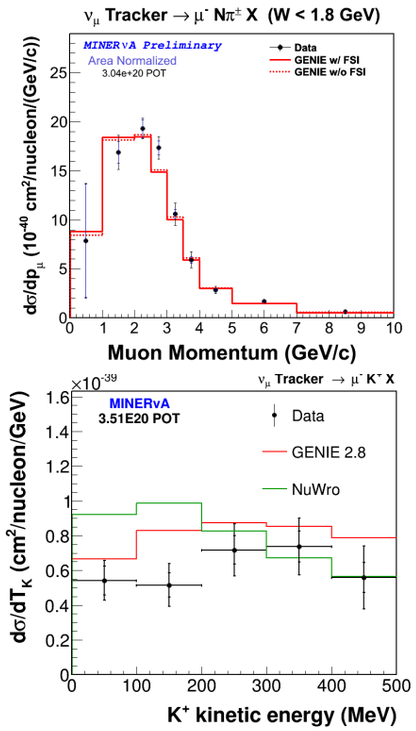
- Completed low-energy run which peaks at 3 GeV (~3.98E20 POT)
- Currently accumulating data in medium-energy run which peaks at 6 GeV (~12.2E20) giving us: more focused beam and factor of 2 increase in cross section.

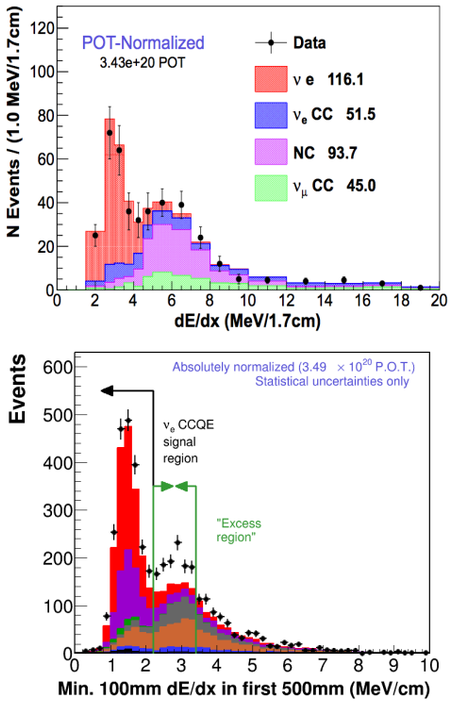
More details: see L. Aliaga talk on Neutrino Flux Predictions for the NuMI Beam at the Users Meeting URA Thesis Award Talk

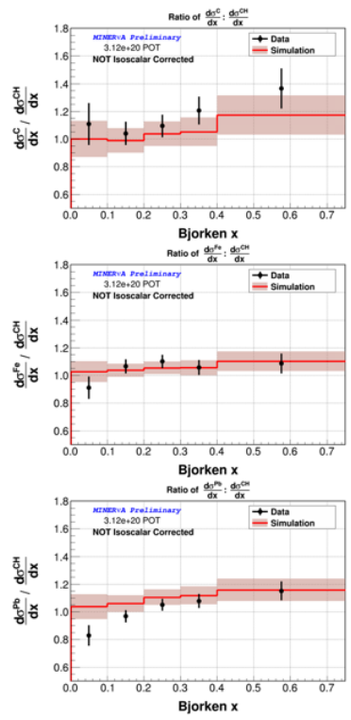
Summary & Outlook

- Low energy data-taking completed giving us many interesting, first-time measurements (20 publications and counting including those with editor!)





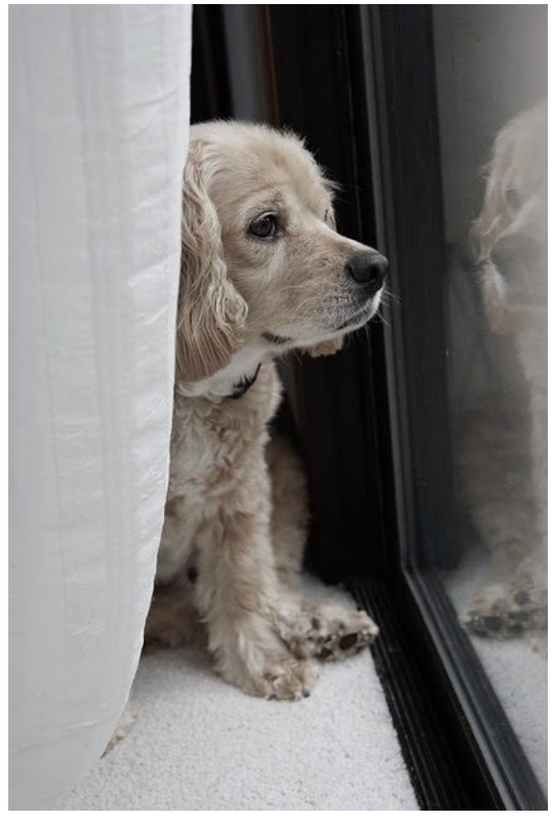




- Data in both neutrino- and antineutrino-enhanced beams used to:
  - study both signal and background reactions relevant to oscillation experiments
  - measure nuclear effects in inclusive and exclusive reactions
- Unique overlap with DUNE flux

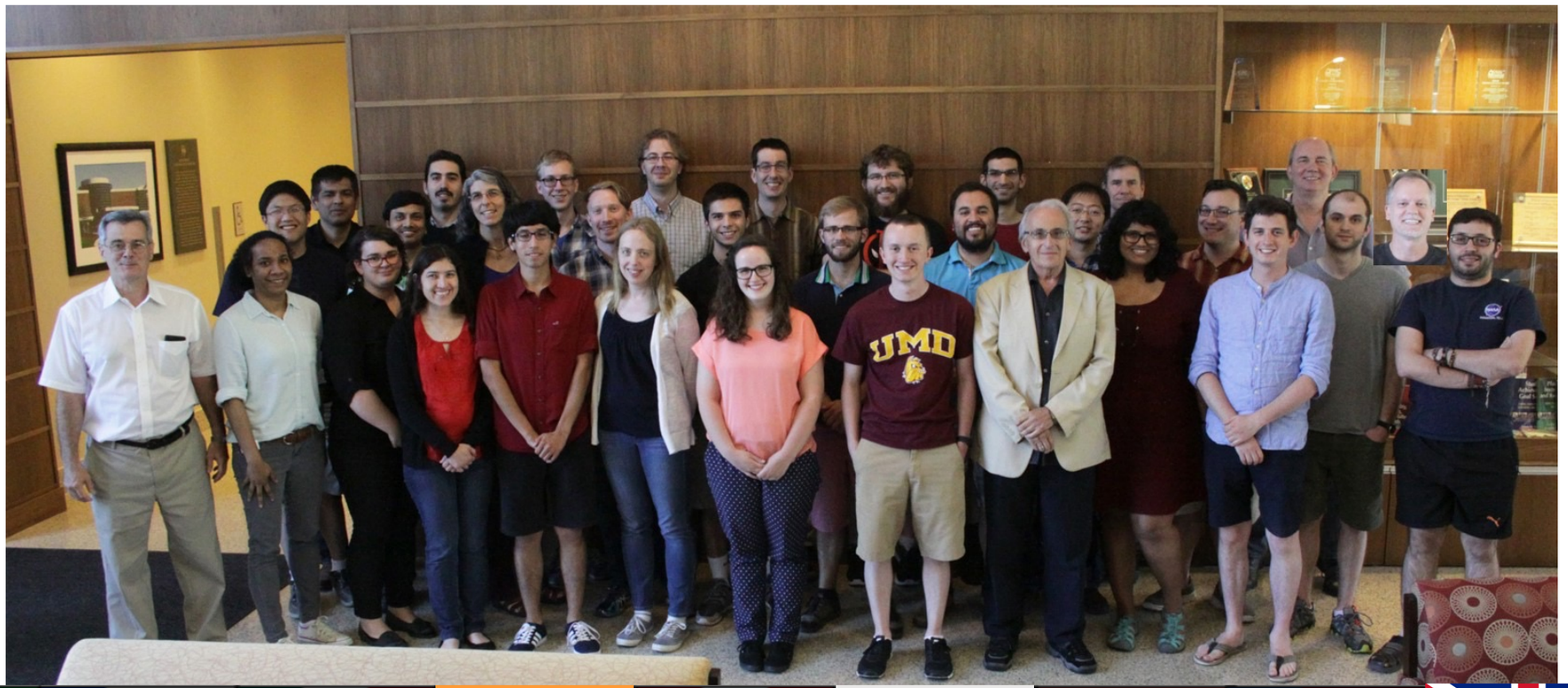
Summary & Outlook

- Medium energy data-taking ongoing (anti-neutrino mode)
  - Higher statistics yields improve comparisons across nuclei, especially for exclusive analysis
  - Access to expanded kinematics and nuclear structure functions, especially for DIS analysis
- Results should continue to improve model descriptions used by both theory and oscillation experiments



From MINERvA Collaboration:

Thank You!!



BACKUP SLIDES

MINERvA Publications (as of June 2017)

- “Direct Measurement of Nuclear Dependence of Charged Current Quasielastic-like Neutrino Interactions using MINERvA”
- “Measurement of the antineutrino to neutrino charged-current interaction cross section ratio on carbon” Phys. Rev. D 95, 072009 (2017)
- “Measurement of neutral-current K+ production by neutrinos using MINERvA”
- “Measurements of the Inclusive Neutrino and Antineutrino Charged Current Cross Sections in MINERvA Using the Low-ν Flux Method” Phys. Rev. D 94, 112007 (2016)
- “Neutrino Flux Predictions for the NuMI Beam” Phys. Rev. D 94, 092005 (2016)
- “First evidence of coherent K+ meson production in neutrino-nucleus scattering” Phys. Rev. Lett. 117, 061802 (2016)
- “Measurement of K+ production in charged-current νμ interactions” Phys. Rev. D 94, 012002 (2016)
- “Cross sections for neutrino and antineutrino induced pion production on hydrocarbon in the few-GeV region using MINERvA”Phys. Rev. D 94, 052005 (2016).
- “Evidence for neutral-current diffractive neutral pion production from hydrogen in neutrino interactions on hydrocarbon” Phys. Rev. Lett. 117, 111801 (2016)
- “Measurement of Neutrino Flux using Neutrino-Electron Elastic Scattering”, Phys. Rev. D 93, 112007 (2016)
- “Measurement of Partonic Nuclear Effects in Deep-Inelastic Neutrino Scattering using MINERvA”, Phys. Rev. D 93, 071101 (2016).
- “Identification of nuclear effects in neutrino-carbon interactions at low three-momentum transfer”, Phys. Rev. Lett. 116, 071802 (2016).
- “Measurement of electron neutrino quasielastic and quasielastic-like scattering on hydrocarbon at average Ev of 3.6 GeV”, Phys. Rev. Lett 116, 081802 (2016).
- “Single neutral pion production by charged-current anti-νμ interactions on hydrocarbon at average Ev of 3.6 GeV”, Phys.Lett. B749 130-136 (2015).
- “Measurement of muon plus proton final states in νμ Interactions on Hydrocarbon at average Ev of 4.2 GeV” Phys. Rev. D91, 071301 (2015).
- “MINERvA neutrino detector response measured with test beam data”, Nucl. Inst. Meth. A789, pp 28-42 (2015).
- “Measurement of Coherent Production of π± in Neutrino and Anti-Neutrino Beams on Carbon from Ev of 1.5 to 20 GeV”, Phys. Rev.Lett. 113, 261802 (2014).
- “Charged Pion Production in νμ Interactions on Hydrocarbon at average Ev of 4.0 GeV” , Phys.Rev. D92, 092008 (2015).
- “Measurement of ratios of νμ charged-current cross sections on C, Fe, and Pb to CH at neutrino energies 2–20 GeV”, Phys. Rev. Lett. 112, 231801 (2014).
- “Measurement of Muon Neutrino Quasi-Elastic Scattering on a Hydrocarbon Target at Ev~3.5 GeV”, Phys. Rev. Lett. 111, 022502 (2013).
- “Measurement of Muon Antineutrino Quasi-Elastic Scattering on a Hydrocarbon Target at Ev~3.5 GeV”, Phys. Rev. Lett. 111, 022501 (2013).

Neutrino Generators

- GENIE

  Widely used by neutrino oscillation and cross section experiments. Comprehensive physics model and tools to support neutrino interaction simulation.

- NuWRO

  Gives predictions for neutrino-nucleus interactions at neutrino energies between **0.1** and **100 GeV.**

- NEUT

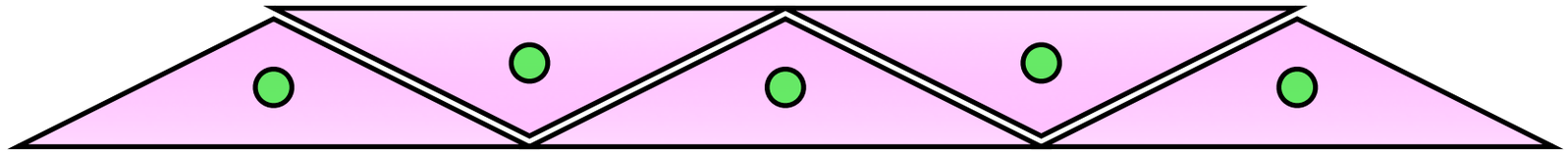
  Developed for Kamiokande, updated continuously for Super-K. Gives background prediction to proton decay in Super-K

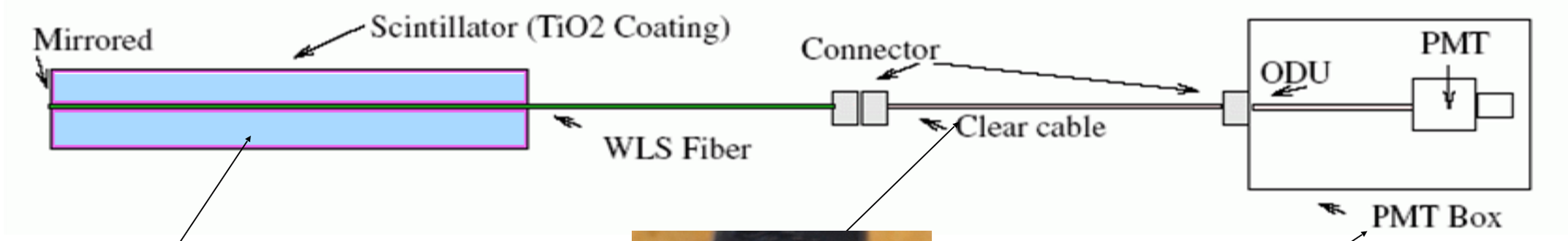
MINERvA Optics

Particle

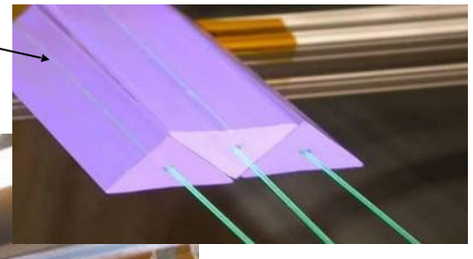
Position determined by charge sharing

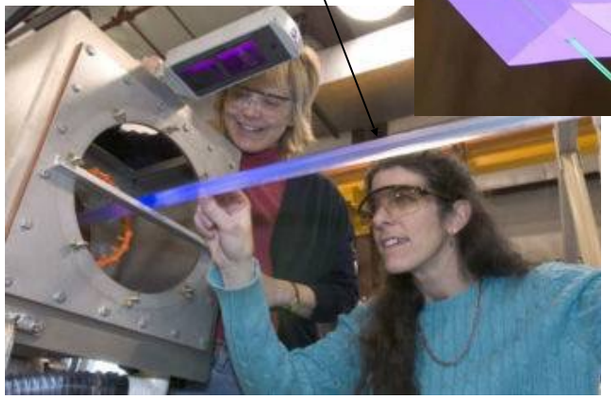
Extrusions built into planar structures.



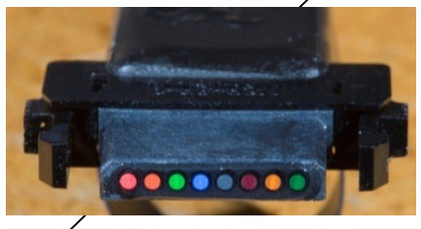


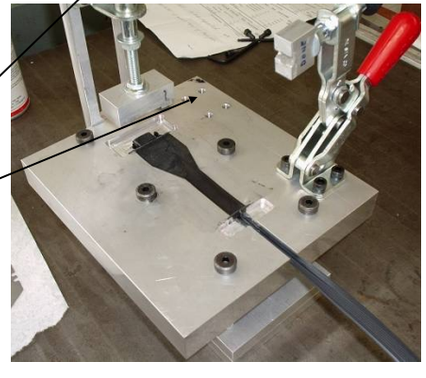
Extruded Scintillator



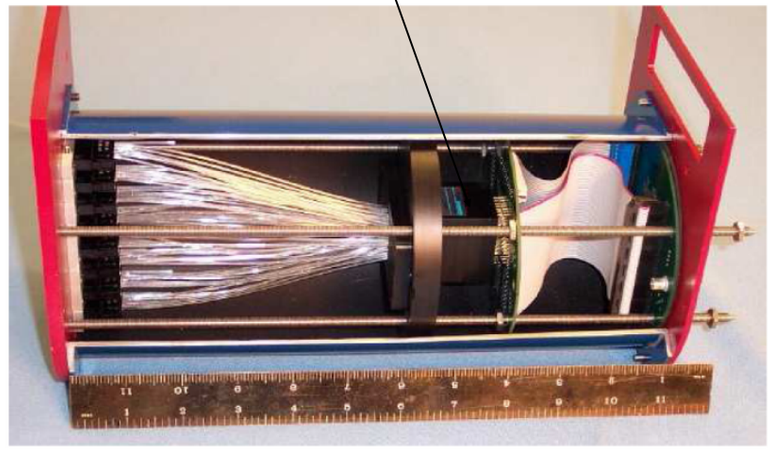


Clear Fiber Cable

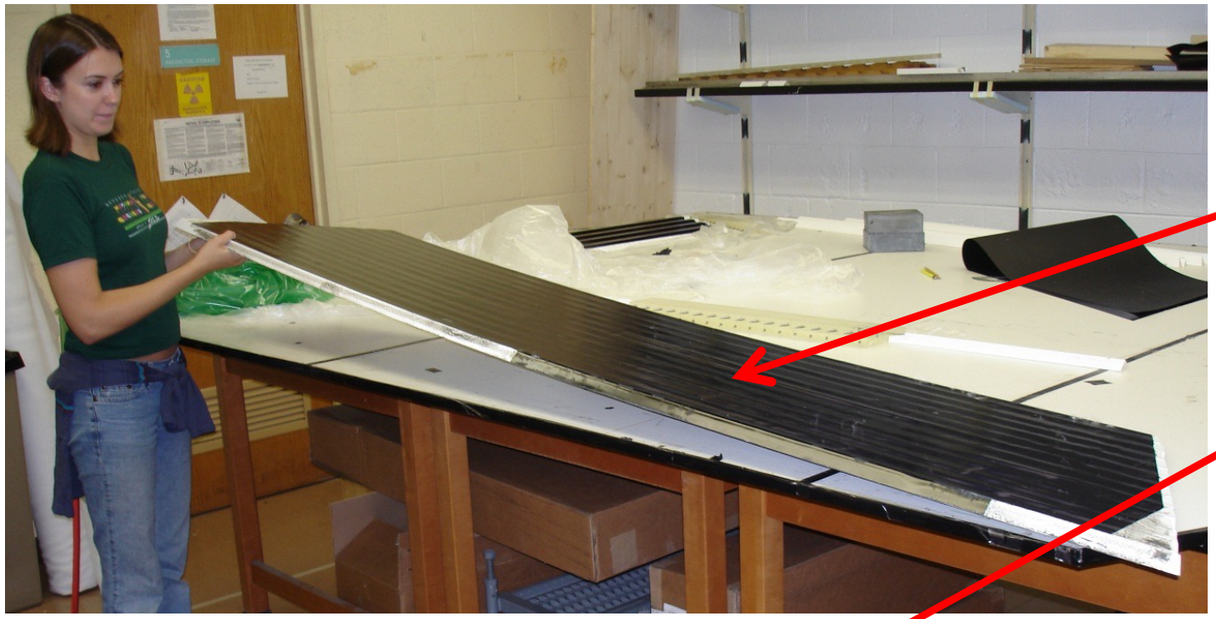


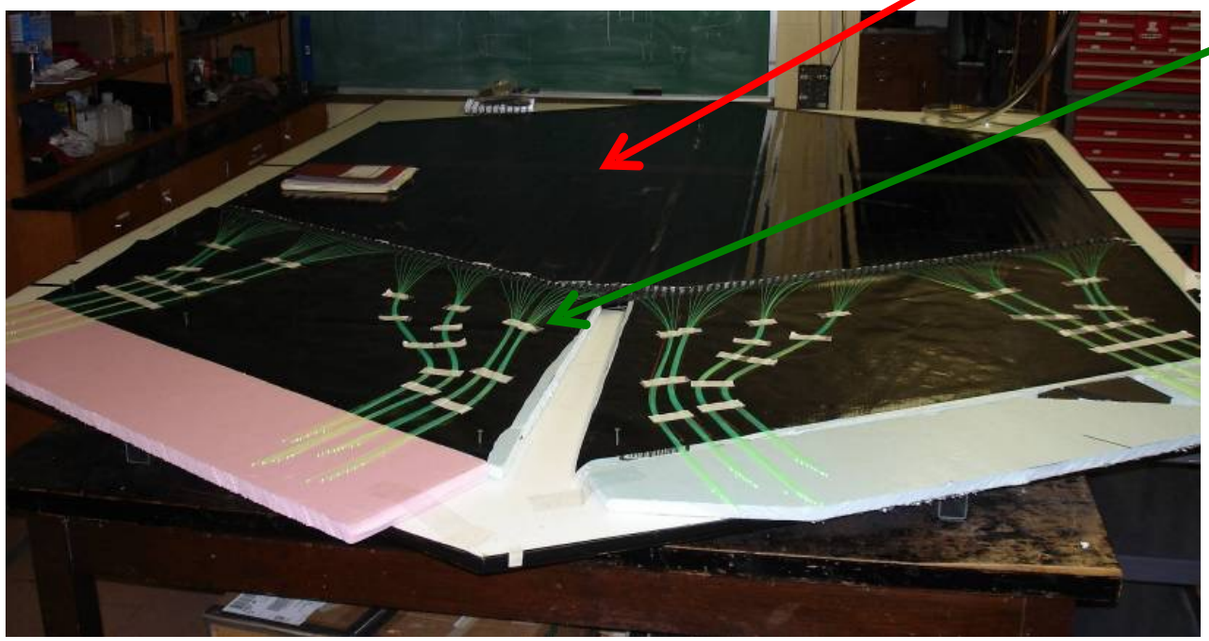


64-Anode PMT

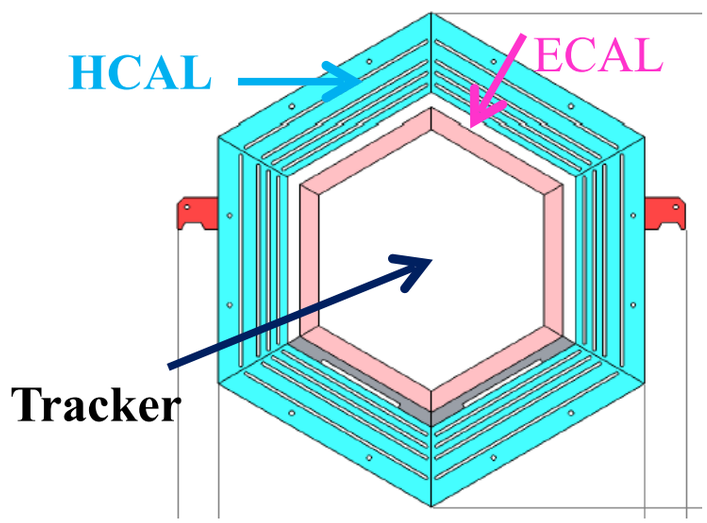


Scintillator Planes

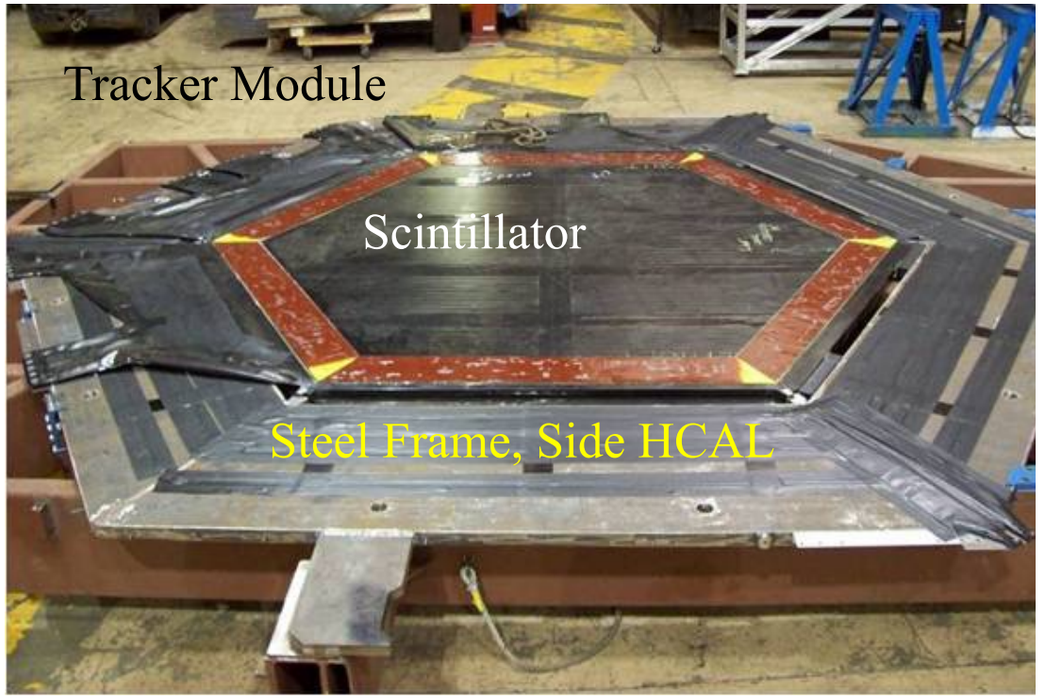




- 1st a set of scintillator pieces are glued in to “planks”
- Then these planks are glued together to form a plane
- The WLS fibers are inserted, routed to connector position and glued



Module Construction



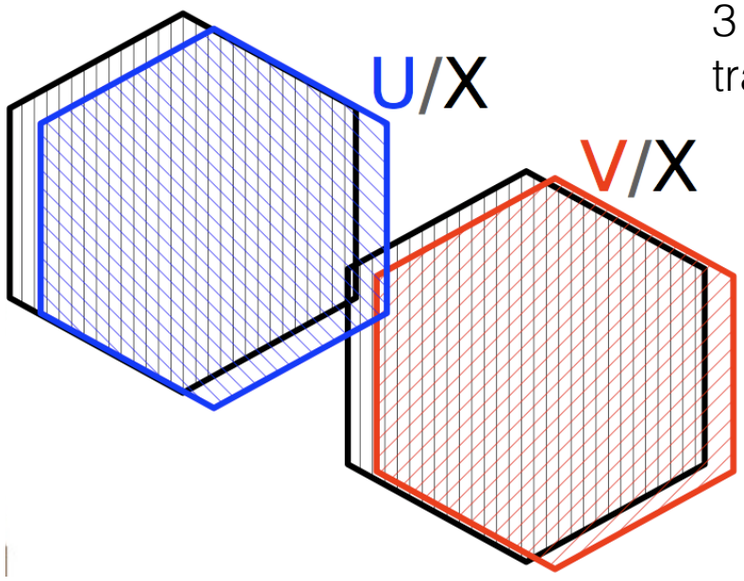
Steel + scintillator = module

Typical module:

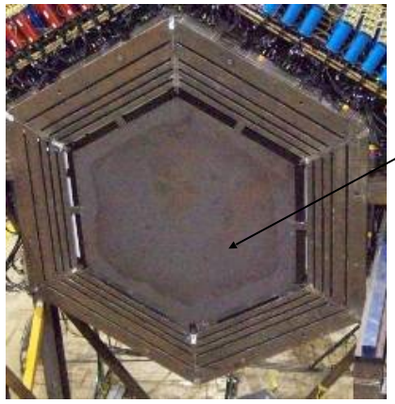
- has 302 scintillator channels
- weighs 3,000 lbs
- 3 types of modules

Full detector:

- 120 modules; ~32K channels.



3 different strip a for 3D tracking



HCAL modules include 1” steel absorber

ECAL modules incorporate 2mm-thick Pb absorber

More on Nuclear Target Region